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Title

Ternary and Quaternary systems in morphoCAs
Some tools for the analysis of number sequences in morphoCAs

Archive-Number / Categories

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Disciplines

Computer Science, Artificial Intelligence and Robotics, Logic and Foundations of Mathematics, Cybernetics, Theory of Science

Abstract

Claviatures gives a glimpse into the usefulness of the sub-rule approach for all kind of cellular automata. The merits of the sub-rule approach becomes evident for highly complex automata where it is practically not achievable to manipulate all single rules of the automaton explicitly.

The topics that can be studied more directly are "number sequences" and "ternary and quaternary logics" related to morphoCAs.

Some preliminary results concerning number sequences for morphoCAs are sketched. The presented techniques might be used as tools for further elaborations.

Citation Information / How to cite

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| K05 Interactivity | K12 Cellular Automata |
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Ternary and Quaternary systems in morphoCAs

Some tools for the analysis of number sequences in morphoCAs

Dr. phil Rudolf Kaehr
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(work in progress, v. 0.2, August 2015)

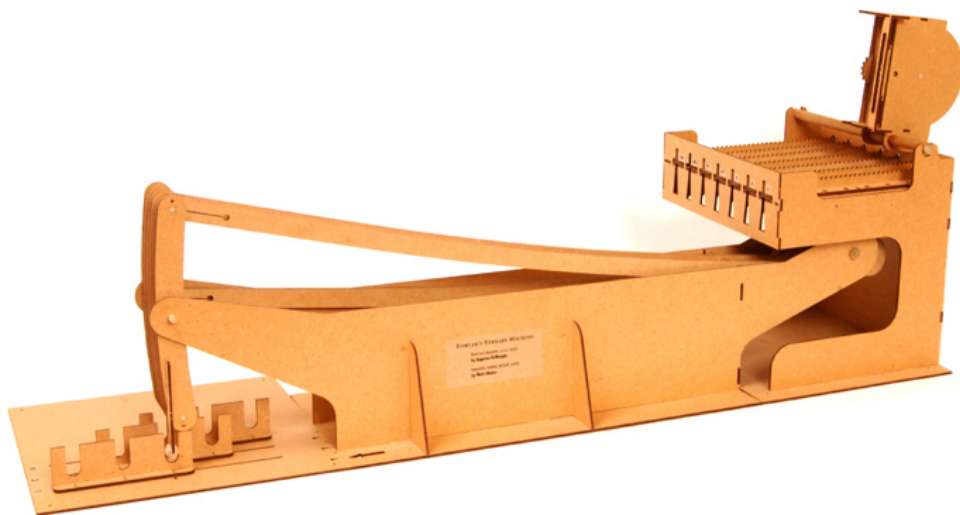
Motivation

Claviatures gives a glimpse into the usefulness of the sub-rule approach for all kind of cellular automata. The merits of the sub-rule approach becomes evident for highly complex automata where it is practically not achievable to manipulate all single rules of the automaton explicitly.

The topics that can be studied more directly are “*number sequences*” and “*ternary and quaternary logics*” related to morphoCAs.

Some preliminary results concerning number sequences for morphoCAs are sketched.

The presented techniques might be used as tools for further elaborations.



http://www.mortati.com/glusker/fowler/The_ternary_calculating_machine_of_Thomas_Fowler

Initialization

Requisits

Morphogram: ruleDCKV

Interface for the Morphogram: ruleDCKV simulation.

Rule Table:

a	1111	1112		
b	1121	1122	1123	
c	1211	1212	1213	
d	1221	1222	1223	
e	2121	2122	2123	
f	2211	2212	2213	
g	2221	2222	2223	
h	2111	2112	2113	
i	2131	2132	2133	2130
j	1231	1232	1233	1230
k	2231	2232	2233	2230
l	2311	2312	2313	2310
m	2321	2322	2323	2320
n	2331	2332	2333	2330
o	2301	2302	2303	2300

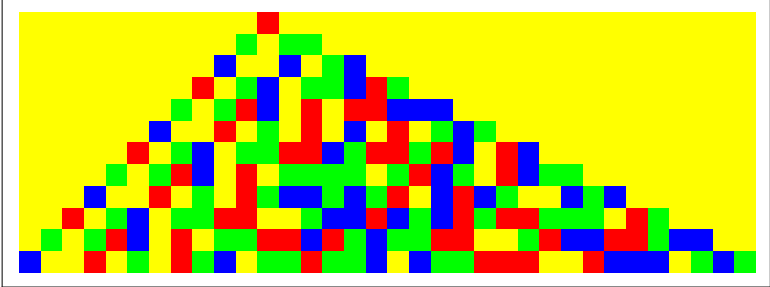
Parameters:

width: ☐ 2 ☐ 3 ☒ 4 ☐ 5

mesh: ☐

steps:

Simulation Result:



a	1111	1112		
b	1121	1122	1123	
c	1211	1212	1213	
d	1221	1222	1223	
e	2121	2122	2123	
f	2211	2212	2213	
g	2221	2222	2223	
h	2111	2112	2113	
i	2131	2132	2133	2130
j	1231	1232	1233	1230
k	2231	2232	2233	2230
l	2311	2312	2313	2310
m	2321	2322	2323	2320
n	2331	2332	2333	2330
o	2301	2302	2303	2300

width

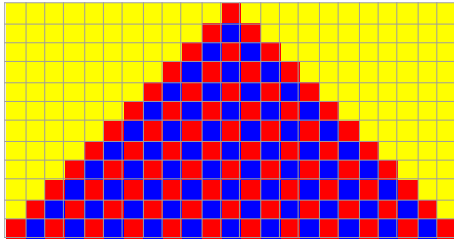
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mesh ☐

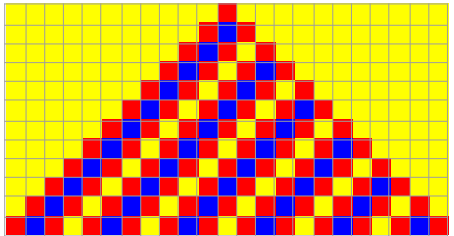
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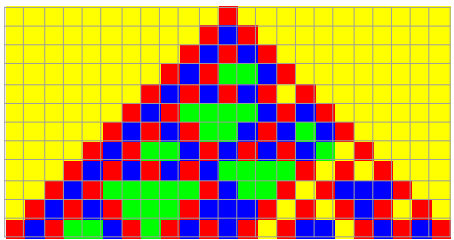
Emphasis on the architectonic symmetry



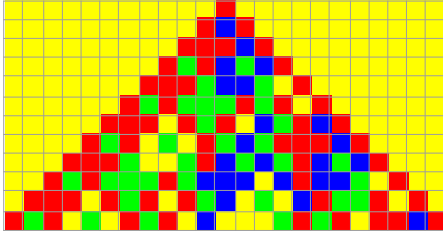
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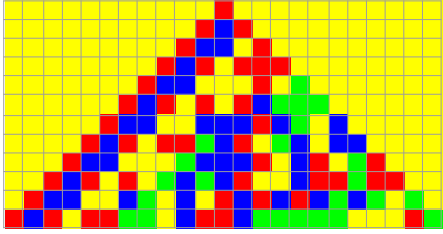
$$\left(\begin{array}{c} \{1\} \\ \{1, 2, 1\} \\ \{1, 2, 1, 0, 1\} \\ \{1, 2, 1, 0, 1, 2, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1\} \\ \{1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1, 0, 1, 2, 1\} \end{array} \right), \left(\begin{array}{c} 1 \\ 9 \\ 37 \\ 153 \\ 613 \\ 2457 \\ 9829 \\ 39321 \\ 157285 \\ 629145 \\ 2516581 \\ 10066329 \end{array} \right)$$



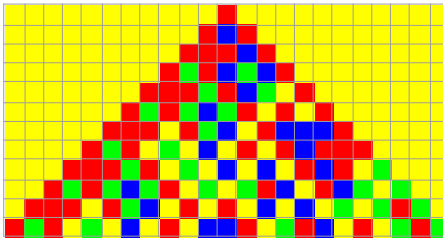
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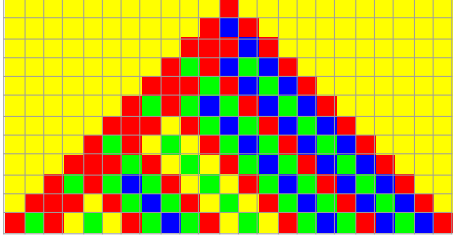
$$\left(\begin{array}{c} \{1\} \\ \{1, 2, 1\} \\ \{1, 1, 1, 2, 1\} \\ \{1, 3, 1, 2, 3, 2, 1\} \\ \{1, 1, 1, 3, 2, 2, 3, 0, 1\} \\ \{1, 3, 1, 3, 3, 3, 1, 3, 1, 0, 1\} \\ \{1, 1, 1, 0, 1, 3, 1, 0, 2, 3, 1, 2, 1\} \\ \{1, 3, 1, 0, 3, 0, 1, 3, 2, 3, 1, 1, 1, 2, 1\} \\ \{1, 1, 1, 3, 0, 0, 3, 1, 2, 3, 2, 3, 1, 2, 3, 2, 1\} \\ \{1, 3, 1, 3, 3, 3, 1, 3, 2, 2, 2, 0, 2, 1, 2, 2, 3, 0, 1\} \\ \{1, 1, 1, 0, 1, 3, 1, 0, 1, 3, 2, 0, 3, 0, 2, 1, 3, 3, 1, 0, 1\} \\ \{1, 3, 1, 0, 3, 0, 1, 3, 1, 0, 2, 0, 0, 0, 3, 1, 3, 1, 0, 1, 1, 2, 1\} \end{array} \right), \left(\begin{array}{c} 1 \\ 9 \\ 33 \\ 209 \\ 605 \\ 3533 \\ 7937 \\ 49025 \\ 144017 \\ 906973 \\ 2028525 \\ 12510321 \end{array} \right)$$



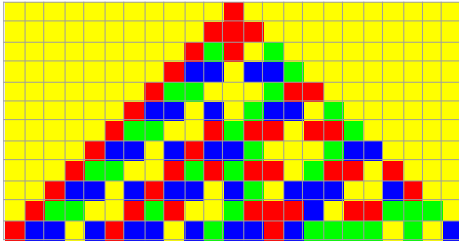
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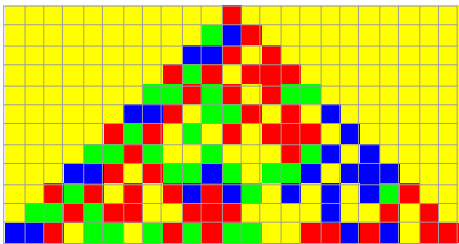
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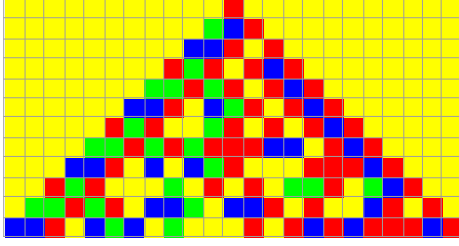
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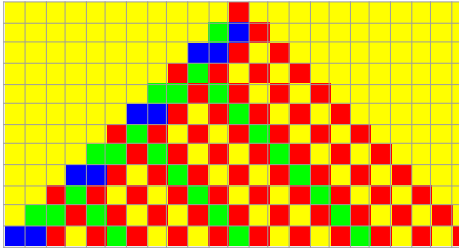
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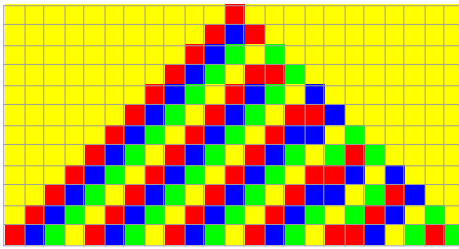
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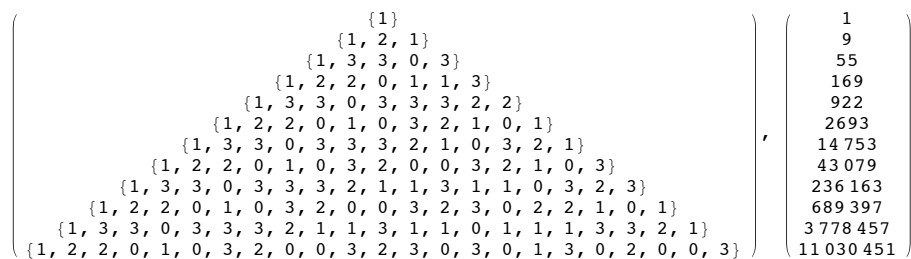
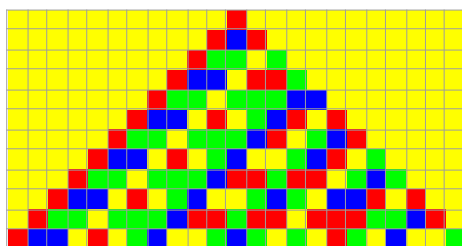
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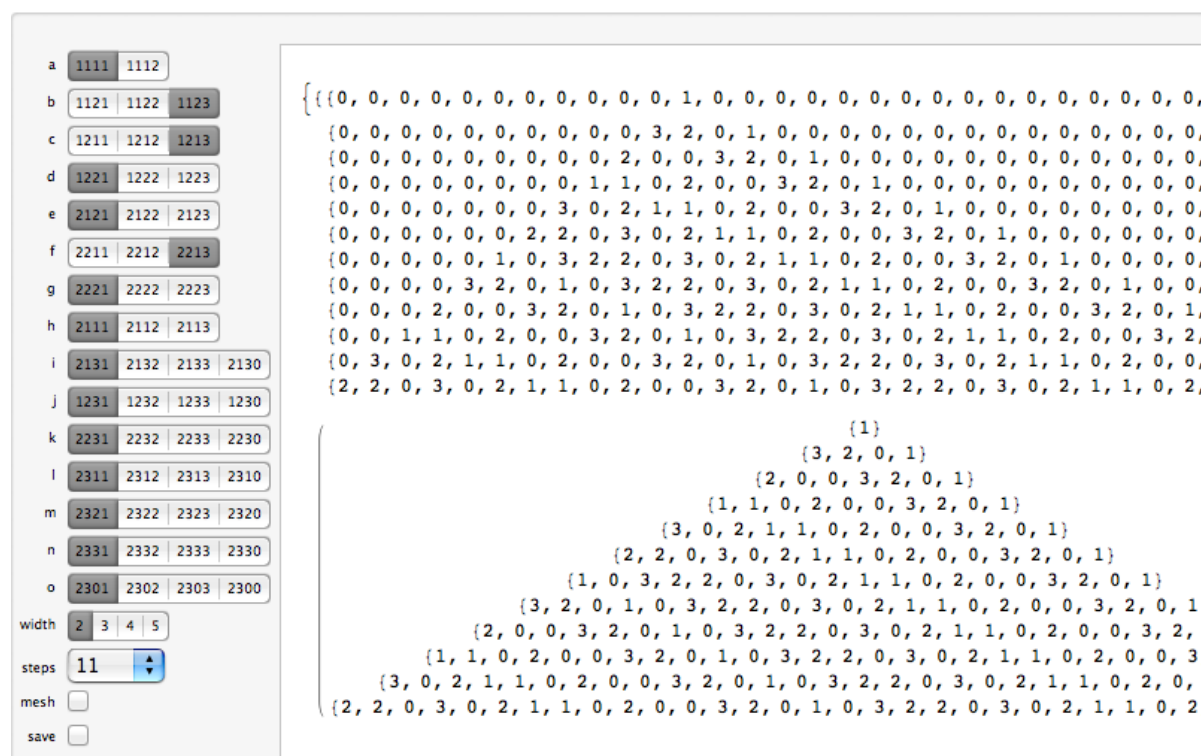
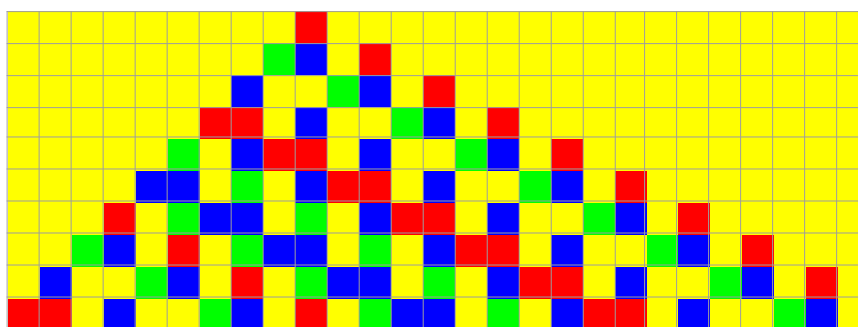
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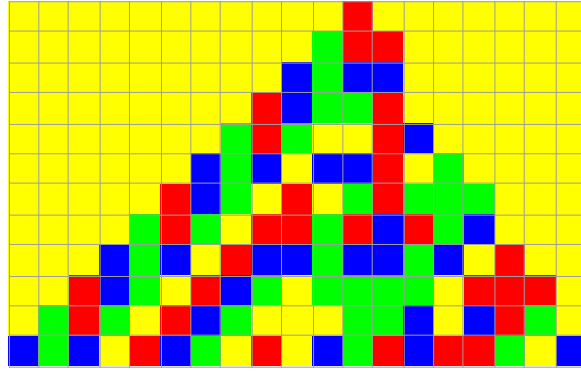


$$\left(\begin{array}{c} \{1\} \\ \{1, 2, 1\} \\ \{1, 2, 3, 0, 3\} \\ \{1, 2, 3, 0, 1, 1, 3\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 2\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 1, 2\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 2, 0, 3\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 3, 1, 3\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 1, 2, 0, 2\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 2, 0, 3, 1, 2\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 3, 1, 2, 0, 3\} \\ \{1, 2, 3, 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, 1, 2, 0, 3, 1, 3\} \end{array} \right), \left(\begin{array}{c} 1 \\ 9 \\ 47 \\ 185 \\ 750 \\ 3000 \\ 12011 \\ 48065 \\ 192226 \\ 768944 \\ 3075843 \\ 12303249 \end{array} \right)$$



Emphasis on the architectonic asymmetry of morphoCAs with radius = $(r, 2r)$





a 1111 1112

b 1121 1122 1123

c 1211 1212 1213

d 1221 1222 1223

e 2121 2122 2123

f 2211 2212 2213

g 2221 2222 2223

h 2111 2112 2113

i 2131 2132 2133 2130

j 1231 1232 1233 1230

k 2231 2232 2233 2230

l 2311 2312 2313 2310

m 2321 2322 2323 2320

n 2331 2332 2333 2330

o 2301 2302 2303 2300

width 2 3 4 5

steps ▼

mesh ☐

save ☐

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    { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0,
    { 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 3, 1, 3, 0, 0, 0, 0, 0, 0,
    { 0, 0, 0, 0, 0, 0, 0, 0, 3, 0, 2, 3, 3, 0, 0, 2, 0, 0, 0, 0, 0,
    { 0, 0, 0, 0, 0, 0, 2, 0, 2, 3, 1, 1, 0, 1, 0, 2, 0, 0, 0, 0, 0,
    { 0, 0, 0, 0, 0, 1, 0, 3, 3, 1, 0, 2, 1, 2, 2, 3, 2, 0, 0, 0, 0,
    { 0, 0, 0, 0, 3, 0, 3, 2, 2, 1, 2, 1, 1, 1, 0, 2, 0, 1, 0, 0, 0,
    { 0, 0, 0, 2, 0, 1, 2, 1, 0, 2, 3, 2, 1, 3, 0, 3, 1, 1, 1, 0, 0,
    { 0, 0, 1, 0, 1, 2, 2, 0, 2, 3, 3, 1, 3, 0, 0, 1, 2, 1, 3, 0, 0,
    { 0, 3, 0, 2, 2, 3, 3, 2, 3, 1, 0, 3, 0, 2, 2, 1, 2, 3, 0, 2, 0,
    { 2, 0, 2, 1, 1, 3, 2, 3, 1, 0, 3, 3, 2, 1, 3, 2, 3, 0, 2, 2, 2,

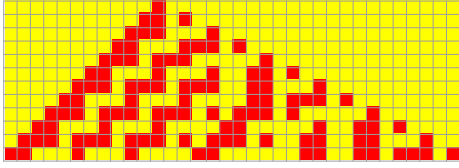
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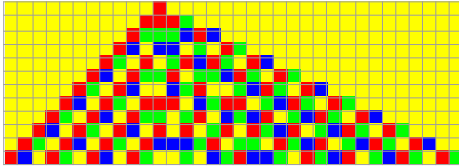
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      { 3, 0, 1 }
      { 2, 0, 1, 1, 1 }
      { 1, 0, 1, 3, 1, 3 }
      { 3, 0, 2, 3, 3, 0, 0, 2 }
      { 2, 0, 2, 3, 1, 1, 0, 1, 0, 2 }
      { 1, 0, 3, 3, 1, 0, 2, 1, 2, 2, 3, 2 }
      { 3, 0, 3, 2, 2, 1, 2, 1, 1, 1, 0, 2, 0, 1 }
      { 2, 0, 1, 2, 1, 0, 2, 3, 2, 1, 3, 0, 3, 1, 1, 1 }
      { 1, 0, 1, 2, 2, 0, 2, 3, 3, 1, 3, 0, 0, 1, 2, 1, 3 }
      { 3, 0, 2, 2, 3, 3, 2, 3, 1, 0, 3, 0, 2, 2, 1, 2, 3, 0, 2 }
      { 2, 0, 2, 1, 1, 3, 2, 3, 1, 0, 3, 3, 2, 1, 3, 2, 3, 0, 2, 2,

```

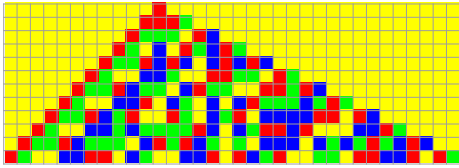
Some selected configurations



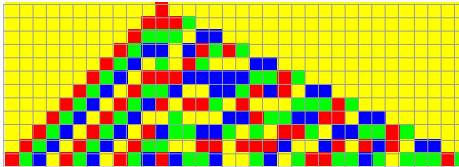
$$\left(\begin{array}{c} \{1\} \\ \{1, 1, 0, 1\} \\ \{1, 1, 1, 0, 0, 1\} \\ \{1, 1, 0, 0, 1, 1, 0, 1\} \\ \{1, 1, 1, 0, 1, 1, 0, 0, 0, 1\} \\ \{1, 1, 0, 1, 1, 1, 0, 0, 1, 0, 1\} \\ \{1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 0, 1\} \\ \{1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1\} \\ \{1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 1\} \\ \{1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 0, 1\} \\ \{1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1\} \\ \{1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 0, 1\} \end{array} \right) \cdot \left(\begin{array}{c} 1 \\ 13 \\ 113 \\ 797 \\ 7617 \\ 50253 \\ 489265 \\ 3215581 \\ 31315777 \\ 205795405 \\ 2004210481 \\ 13170904285 \end{array} \right)$$



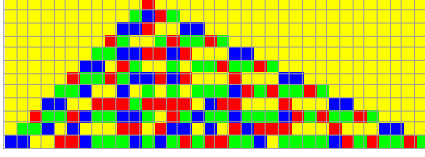
$$\left(\begin{array}{c} \{1\} \\ \{1, 1, 3\} \\ \{1, 3, 3, 1, 2\} \\ \{1, 3, 0, 2, 2, 0, 3, 0, 1, 3\} \\ \{1, 3, 0, 1, 0, 3, 1, 2, 1, 3, 0, 1, 2\} \\ \{1, 2, 0, 1, 3, 3, 1, 0, 3, 3, 2, 1, 3, 0, 1, 3\} \\ \{1, 3, 0, 1, 2, 0, 0, 2, 3, 1, 0, 0, 3, 2, 1, 3, 0, 1, 2\} \\ \{1, 2, 0, 1, 3, 0, 1, 1, 0, 2, 3, 1, 1, 0, 3, 2, 1, 3, 0, 1, 3\} \\ \{1, 3, 0, 1, 2, 0, 1, 3, 3, 0, 3, 1, 0, 2, 3, 2, 1, 0, 3, 2, 1, 3, 0, 1, 2\} \\ \{1, 2, 0, 1, 3, 0, 1, 2, 0, 1, 0, 3, 1, 0, 1, 3, 2, 1, 0, 3, 2, 1, 3, 0, 1, 3\} \\ \{1, 3, 0, 1, 2, 0, 1, 3, 0, 1, 2, 2, 2, 3, 1, 0, 3, 3, 0, 1, 3, 2, 1, 0, 3, 2, 1, 3, 0, 1, 2\} \\ \{1, 2, 0, 1, 3, 0, 1, 2, 0, 1, 3, 0, 0, 3, 0, 2, 3, 1, 2, 2, 3, 0, 1, 3, 2, 1, 0, 3, 2, 1, 3, 0, 1, 3\} \end{array} \right) \cdot \left(\begin{array}{c} 1 \\ 17 \\ 244 \\ 1245 \\ 11308 \\ 80045 \\ 728876 \\ 4915245 \\ 47055404 \\ 314964525 \\ 3001039404 \\ 20178860589 \end{array} \right)$$



$$\left(\begin{array}{c} \{1\} \\ \{1, 1, 1, 3\} \\ \{1, 3, 3, 3, 0, 1, 2\} \\ \{1, 3, 0, 2, 0, 1, 3, 2, 1, 3\} \\ \{1, 3, 3, 1, 2, 1, 2, 0, 2, 1, 2, 1, 2\} \\ \{1, 3, 0, 0, 2, 2, 3, 0, 0, 1, 1, 3, 3, 0, 1, 3\} \\ \{1, 3, 3, 1, 2, 3, 3, 0, 2, 1, 3, 3, 0, 0, 1, 1, 3, 1, 2\} \\ \{1, 3, 0, 0, 2, 2, 1, 0, 2, 3, 0, 2, 0, 2, 1, 3, 3, 3, 2, 1, 3\} \\ \{1, 3, 3, 1, 2, 3, 1, 0, 0, 1, 3, 0, 2, 3, 1, 0, 2, 2, 2, 1, 1, 0, 1, 2\} \\ \{1, 3, 0, 0, 2, 2, 3, 3, 3, 1, 2, 0, 2, 3, 1, 1, 2, 1, 0, 0, 2, 2, 1, 3\} \\ \{1, 3, 3, 1, 2, 3, 3, 3, 0, 2, 1, 3, 1, 2, 3, 0, 3, 0, 2, 2, 2, 0, 2, 3, 2, 3, 1, 3, 2, 1, 2\} \\ \{1, 3, 0, 0, 2, 2, 1, 1, 0, 2, 3, 0, 0, 2, 2, 1, 0, 1, 2, 3, 1, 0, 0, 3, 3, 0, 1, 1, 2, 2, 1, 0, 1, 3\} \end{array} \right) \cdot \left(\begin{array}{c} 1 \\ 17 \\ 236 \\ 1461 \\ 14644 \\ 89773 \\ 958120 \\ 5700593 \\ 60653532 \\ 372129949 \\ 3941858452 \\ 23349097261 \end{array} \right)$$



$$\left(\begin{array}{c} \{1\} \\ \{1, 1, 1, 3\} \\ \{1, 3, 3, 3, 0, 2, 2\} \\ \{1, 3, 2, 2, 0, 2, 1, 3, 1, 3\} \\ \{1, 3, 2, 0, 3, 0, 1, 3, 0, 0, 2, 2\} \\ \{1, 3, 2, 0, 1, 1, 1, 2, 2, 2, 2, 3, 1, 3\} \\ \{1, 3, 2, 0, 1, 3, 3, 2, 0, 0, 2, 2, 3, 1, 2, 1, 0, 2, 2\} \\ \{1, 3, 2, 0, 1, 3, 2, 1, 0, 1, 1, 3, 0, 1, 0, 0, 3, 3, 1, 3\} \\ \{1, 3, 2, 0, 1, 3, 2, 0, 0, 3, 0, 0, 2, 2, 1, 3, 3, 2, 2, 1, 1, 0, 2, 2\} \\ \{1, 3, 2, 0, 1, 3, 2, 0, 1, 2, 3, 3, 2, 2, 3, 0, 3, 0, 1, 1, 3, 0, 2, 2, 3, 3, 1, 3\} \\ \{1, 3, 2, 0, 1, 3, 2, 0, 1, 3, 3, 0, 0, 1, 1, 0, 1, 1, 2, 0, 0, 2, 1, 0, 1, 2, 1, 0, 2, 2\} \\ \{1, 3, 2, 0, 1, 3, 2, 0, 1, 3, 2, 1, 2, 3, 3, 2, 0, 0, 3, 2, 0, 3, 1, 1, 3, 3, 2, 3, 0, 3, 3, 1, 3\} \end{array} \right) \cdot \left(\begin{array}{c} 1 \\ 17 \\ 238 \\ 1721 \\ 13222 \\ 102921 \\ 844814 \\ 6710617 \\ 53583710 \\ 429587721 \\ 3436413646 \\ 27494860569 \end{array} \right)$$



$$\left(\begin{array}{c} \{1\} \\ \{3, 2, 1, 3\} \\ \{2, 2, 1, 0, 0, 2, 2\} \\ \{1, 3, 0, 0, 3, 1, 3, 3, 1, 3\} \\ \{3, 3, 2, 2, 1, 1, 2, 1, 0, 0, 2, 2\} \\ \{2, 2, 0, 1, 3, 0, 0, 3, 0, 3, 1, 3, 3, 1, 3\} \\ \{1, 3, 3, 1, 2, 2, 1, 2, 1, 0, 0, 0, 1, 0, 0, 2, 2\} \\ \{3, 3, 2, 0, 2, 0, 3, 0, 3, 3, 2, 1, 3, 1, 3, 3, 1, 3\} \\ \{2, 2, 0, 0, 1, 1, 1, 3, 1, 1, 1, 0, 2, 1, 1, 0, 0, 0, 1, 0, 0, 2, 2\} \\ \{1, 3, 3, 1, 2, 3, 3, 2, 2, 3, 0, 1, 3, 2, 3, 3, 2, 3, 3, 2, 1, 3, 1, 3, 3, 1, 3\} \\ \{3, 3, 2, 0, 2, 0, 0, 1, 1, 0, 1, 2, 2, 0, 2, 0, 1, 2, 1, 1, 1, 0, 0, 1, 0, 0, 2, 2\} \\ \{2, 2, 0, 0, 1, 1, 2, 3, 3, 3, 2, 3, 2, 3, 1, 3, 1, 3, 3, 2, 0, 3, 3, 3, 2, 1, 3, 1, 3, 3, 1, 3\} \end{array} \right), \left(\begin{array}{c} 1 \\ 37 \\ 214 \\ 1433 \\ 22\,054 \\ 109\,657 \\ 963\,110 \\ 10\,684\,121 \\ 52\,688\,422 \\ 492\,811\,993 \\ 5\,510\,614\,566 \\ 27\,234\,250\,457 \end{array} \right)$$

Reduction example: $\text{morphoCA}^{(5,4,5)} \Rightarrow \text{morphoCA}^{(5,2,5)}$

Reductions are an essential strategy for the study of morphoCAs. They are complementing the well known ECA techniques of *elimination*, *reversion* and *dualizations*. The proposed reductions by mapping the numeric presentation of the morphoCAs to a lower valued but isomorphic morphoCA is certainly just a quite simple first step. All reductive mappings that are preserving the structure of the output of the morphoCAs are natural candidates for reduction procedures.

Automata in comparison are: ECA, morphDCM and morphoDM. The automaton morphoDCM is a restriction of morphoDM and is implementing the system $\text{morphoCA}^{(3,3)}$ that is restricted to the first 14 morphograms and functions with just 3 colors instead of 4 colors as for morphoDM are implemented. The system $\text{morphoCA}^{(3,3)}$ is to some parts a direct sub-system of morphoDM.

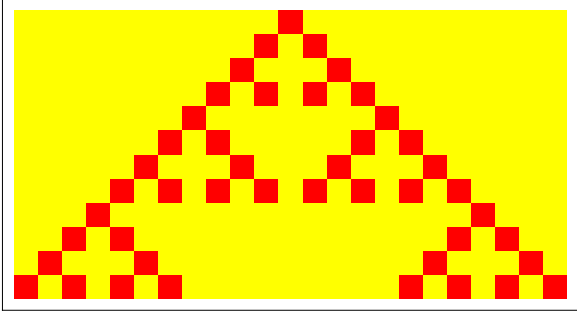
Sub - rule ECA

k 1 6
 l 2 7
 m 3 8
 n 4 9
 o 5 10
 p 11 12
 q 13 14
 r 15 16

width 2 3 4 5

mesh

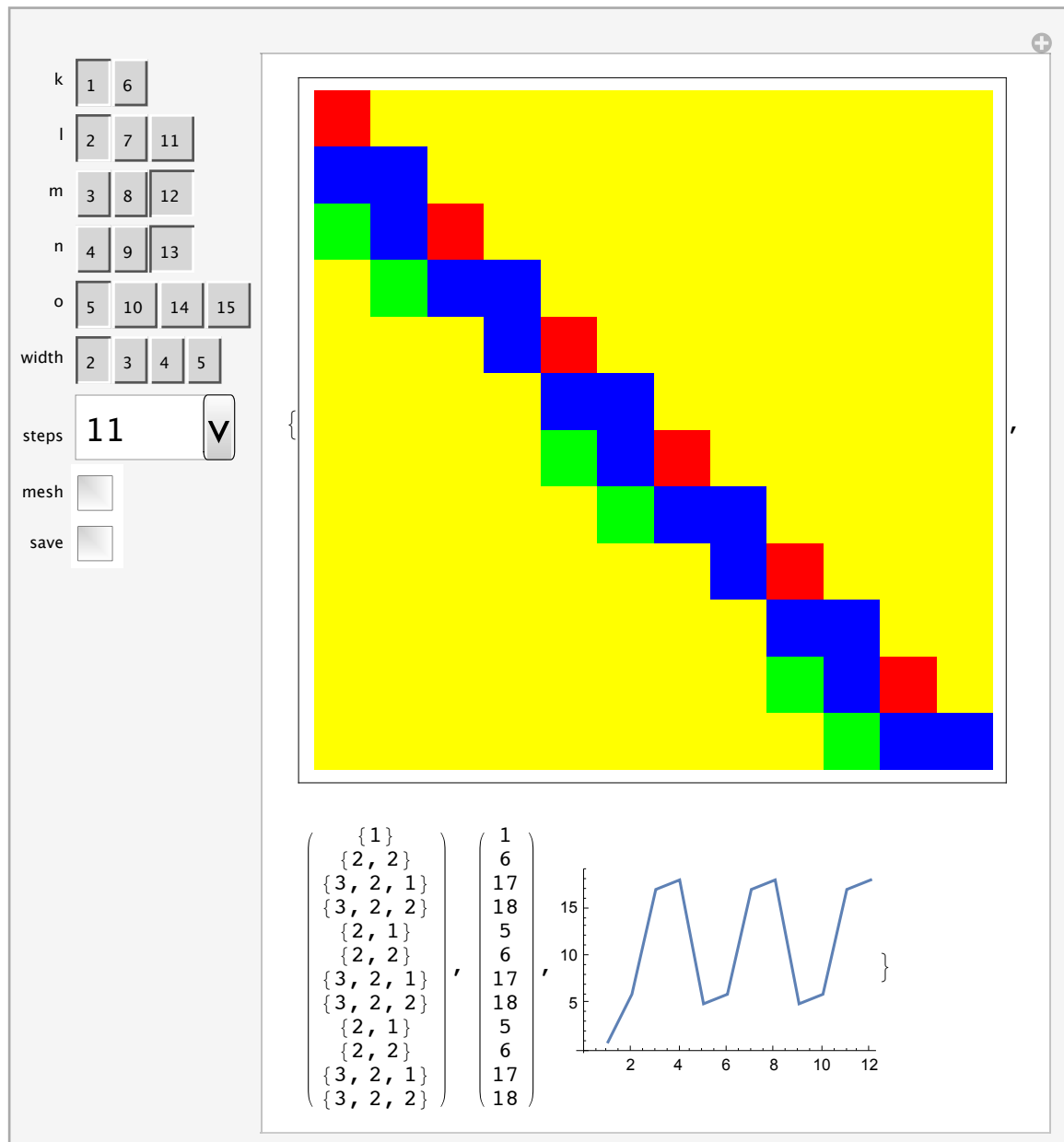
steps 11 v



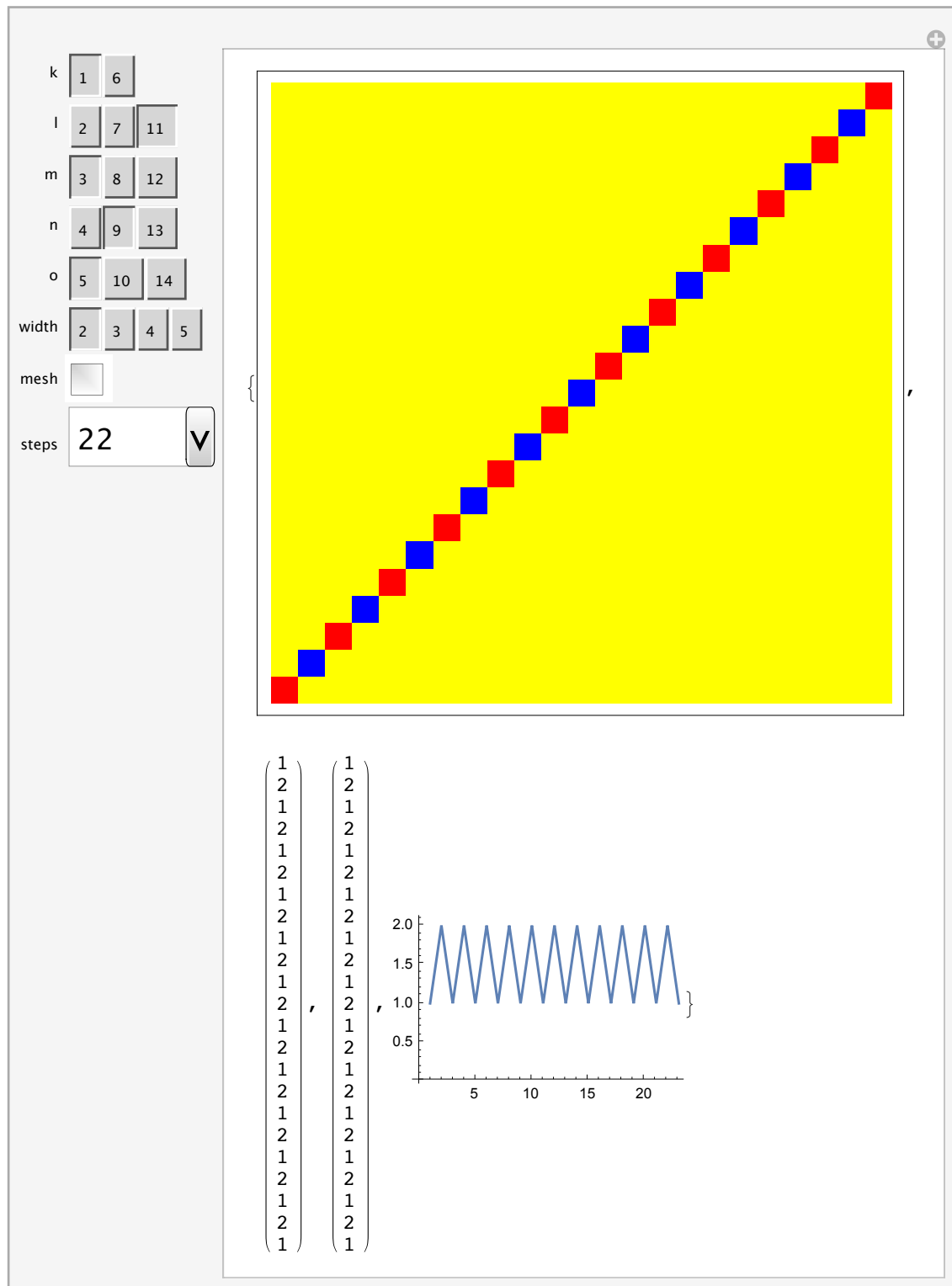
```

      {
      {
      {1}
      {1, 0, 1}
      {1, 0, 0, 0, 1}
      {1, 0, 1, 0, 1, 0, 1}
      {1, 0, 0, 0, 0, 0, 0, 0, 1}
      {1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1}
      {1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1}
      {1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}
      {1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1}
      {1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1}
      {1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1}
      {1, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 1}
      }
      }
    
```

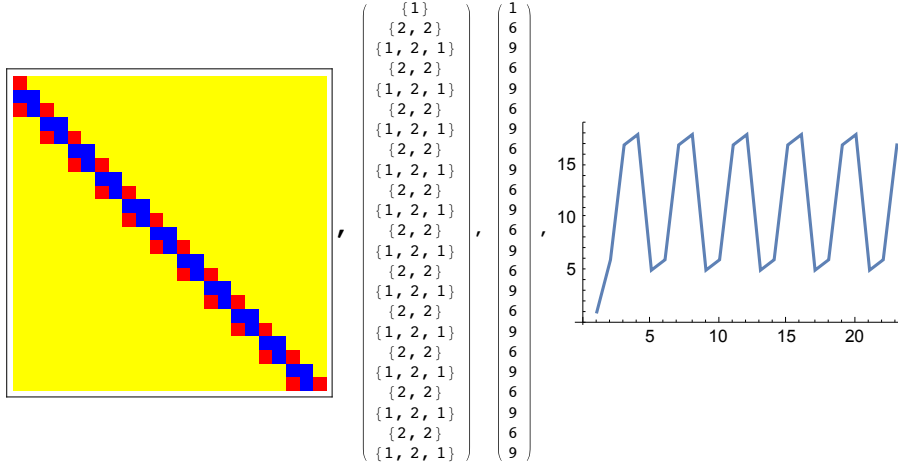
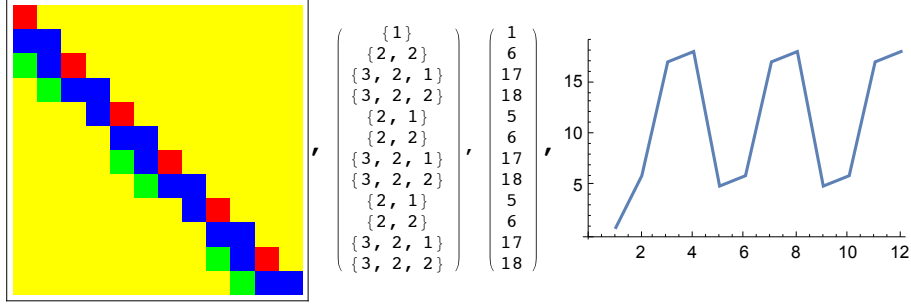
Sub - rule morphoDM



Sub – rule morphoDCM^(3,3)



A trivial difference between morphoDM and morphoDCM for rule[1, 2, 12, 13, 5]



Reduction example: $\text{morphoCA}^{(5,3,4)} \Rightarrow \text{ECA}^{(2,2)}$

$$\begin{aligned}
 &\text{ruleDM}[\{1, 11, 3, 13, 15\}] = \\
 &\left(\begin{array}{c} \{1\} \\ \{2, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 3, 0, 3, 0, 2\} \\ \{1, 0, 1, 0, 3, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 3, 0, 3, 0, 2, 0, 3, 0, 3, 0, 1\} \\ \{2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2\} \\ \{1, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 1, 0, 2\} \end{array} \right) \\
 &\quad \Downarrow_{2,3 \rightarrow 1} \\
 &\left(\begin{array}{c} \{1\} \\ \{1, 0, 1\} \\ \{1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \end{array} \right) \\
 &= \text{ruleECA}[\{1, 7, 3, 4, 5, 11, 13, 15\}]
 \end{aligned}$$

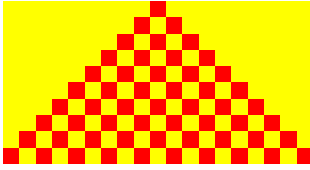
Reduction :

```
ruleDM : {[{1, 7, 3, 13, 5}], [{1, 7, 3, 13, 14}], [{1, 7, 3, 13, 15}],
          [{1, 11, 3, 4, 5}], [{1, 11, 3, 4, 14}], [{1, 11, 3, 4, 15}],
          [{1, 11, 3, 13, 5}], [{1, 11, 3, 13, 14}], [{1, 11, 3, 13, 15}],
          [{1, 7, 3, 4, x}]}
```

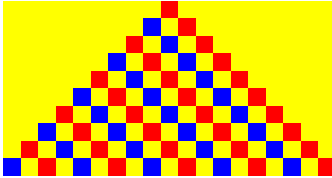
$\Rightarrow_{2,3 \rightarrow 1}$

```
ruleECA[{1, 7, 3, 4, 5, 11, 13, 15}]
```

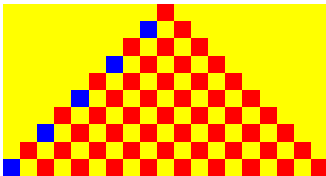
$$\text{ruleDM}[\{1, 7, 3, 4, x\}] = \left(\begin{array}{c} \{1\} \\ \{1, 0, 1\} \\ \{1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \end{array} \right),$$



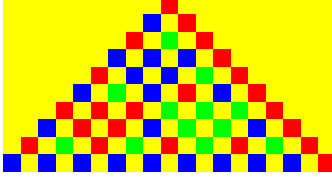
$$\text{ruleDM}[\{1, 11, 3, 4, 5\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 1\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \end{array} \right),$$



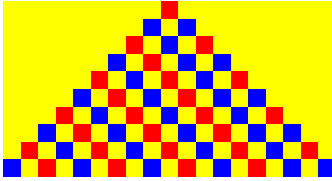
$$\text{ruleDM}[\{1, 11, 3, 4, 14\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 1\} \\ \{1, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \end{array} \right),$$



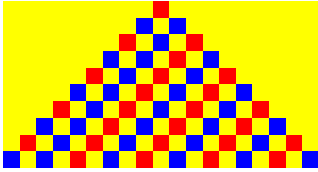
$$\text{ruleDM}[\{1, 11, 3, 4, 15\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 1\} \\ \{1, 0, 3, 0, 1\} \\ \{2, 0, 2, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 2, 0, 3, 0, 1\} \\ \{2, 0, 3, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 3, 0, 3, 0, 3, 0, 1\} \\ \{2, 0, 1, 0, 1, 0, 2, 0, 3, 0, 3, 0, 2, 0, 1\} \\ \{1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1\} \\ \{2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 1\} \end{array} \right),$$



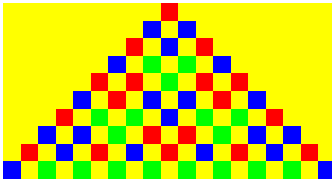
$$\text{ruleDM}[\{1, 11, 3, 13, 5\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 2\} \end{array} \right),$$



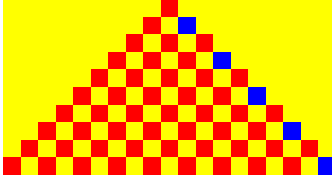
$$\text{ruleDM}[\{1, 11, 3, 13, 14\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \end{array} \right),$$



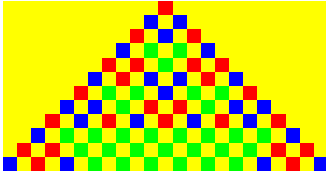
$$\text{ruleDM}[\{1, 11, 3, 13, 15\}] = \left(\begin{array}{c} \{1\} \\ \{2, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 3, 0, 3, 0, 2\} \\ \{1, 0, 1, 0, 3, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 3, 0, 3, 0, 2, 0, 3, 0, 3, 0, 1\} \\ \{2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2\} \end{array} \right),$$



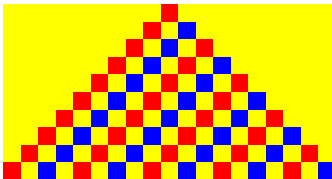
$$\text{ruleDM}[\{1, 7, 3, 13, 5\}] = \left(\begin{array}{c} \{1\} \\ \{1, 0, 2\} \\ \{1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 2\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2\} \end{array} \right),$$



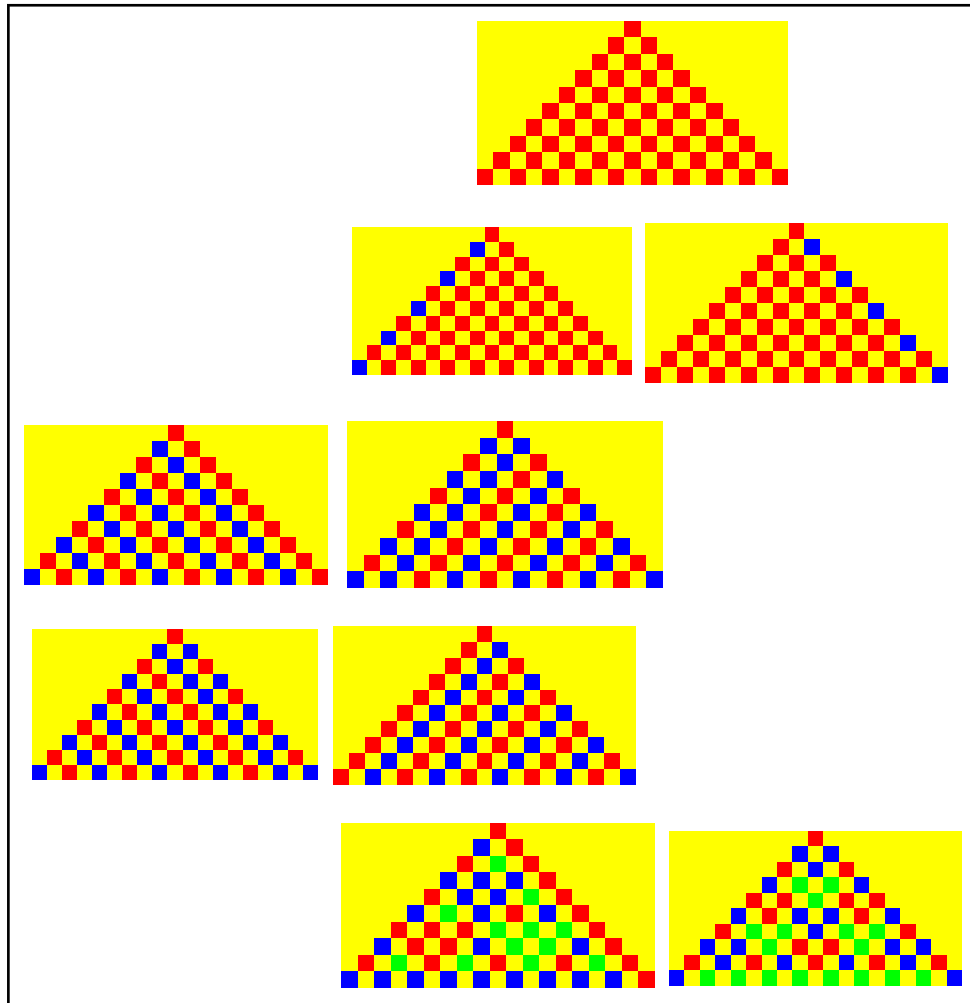
$$\text{ruleDM}[\{1, 7, 3, 13, 15\}] = \left(\begin{array}{c} \{1\} \\ \{1, 0, 2\} \\ \{1, 0, 3, 0, 1\} \\ \{1, 0, 2, 0, 2, 0, 2\} \\ \{1, 0, 3, 0, 2, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 3, 0, 2\} \\ \{1, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 2, 0, 3, 0, 3, 0, 2, 0, 1, 0, 1, 0, 2\} \\ \{1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1\} \\ \{1, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2\} \end{array} \right),$$



$$\text{ruleDM}[\{1, 7, 3, 13, 14\}] = \left(\begin{array}{c} \{1\} \\ \{1, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2\} \end{array} \right),$$

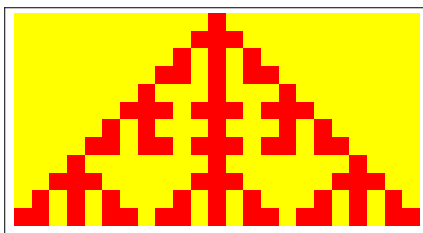


Alternating system of differentiation and reduction



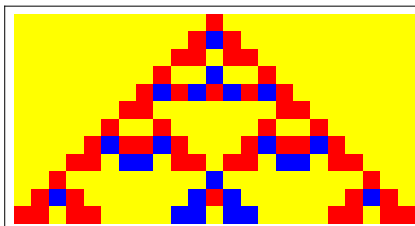
Comparisons

ruleDM[{1, 7, 8, 4, x}], ECA150

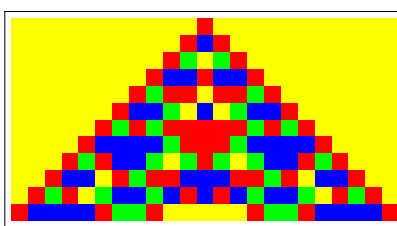


ruleDM[{1, 7, 12, 4, 10}]

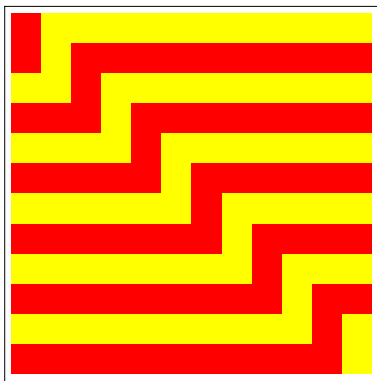
ruleDM[{1, 7, 12, 4, 15}]



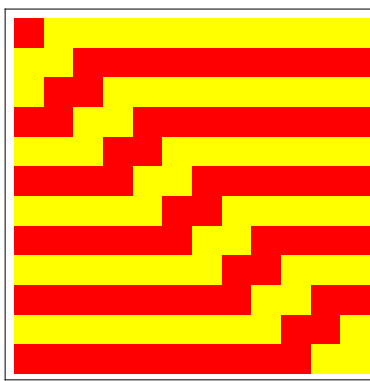
ruleDM[{6, 7, 8, 9, 15}]



ruleDM[{6, 7, 3, 9, 15}]

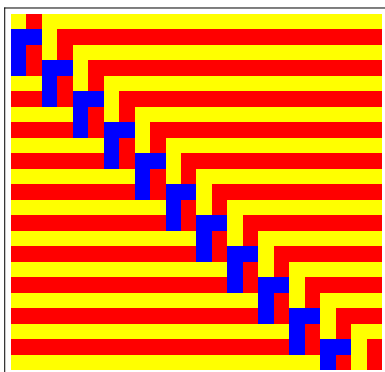
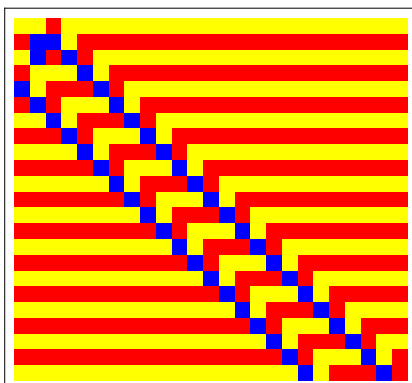


ruleDM[{6, 11, 12, 9, 5}]

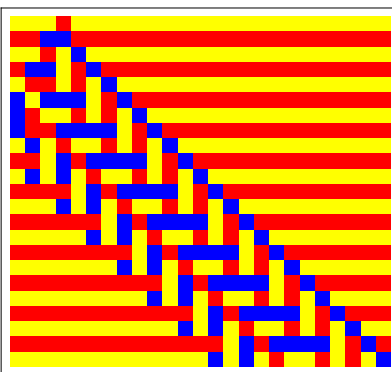


ruleDM[{6, 11, 12, 9, 10}]

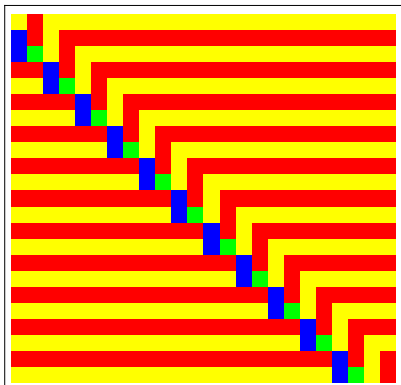
ruleDM[{6, 11, 12, 4, 10}]



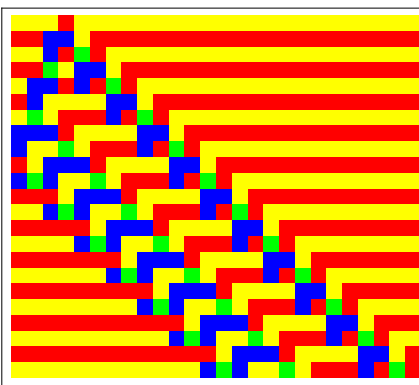
ruleDM[{6, 11, 8, 9, 15}]



ruleDM[{6, 11, 12, 9, 15}]



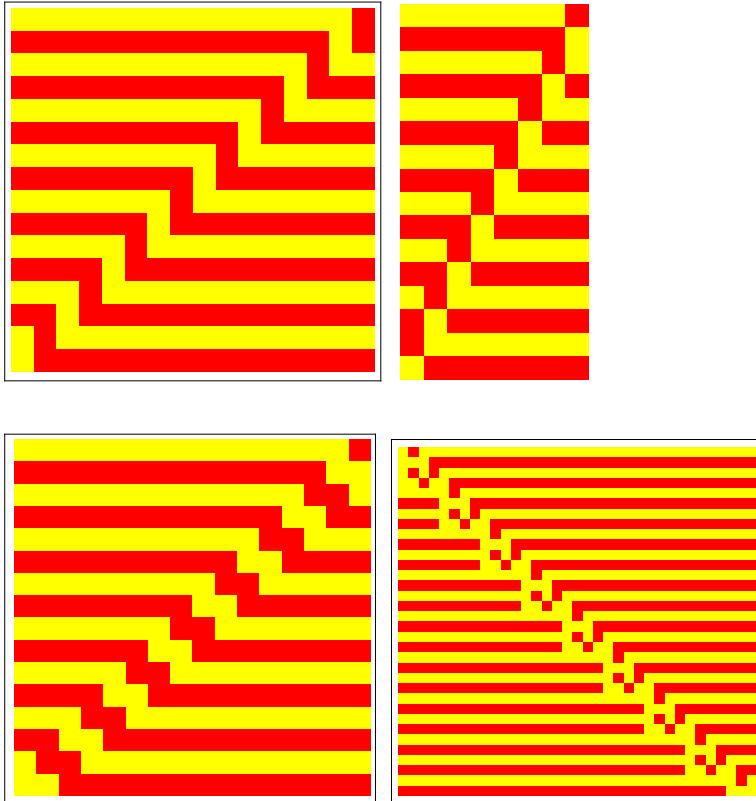
ECA 170



ECA 202

ECA 138

ECA 148



Analogues to code 420, NKS p.63

"In detail, some of the patterns are definitely more complicated than those seen in elementary rules. But at the level of overall behavior, there are no fundamental differences. [...]"

The only new structure not seen in elementary rules is the one in code 420 - but this occurs only quite rarely."
(NKS, p. 65)

Interestingly, the difference of code 420 to ECA rule is an internal difference of the produced patterns and is not considering the underlying architectonic design.

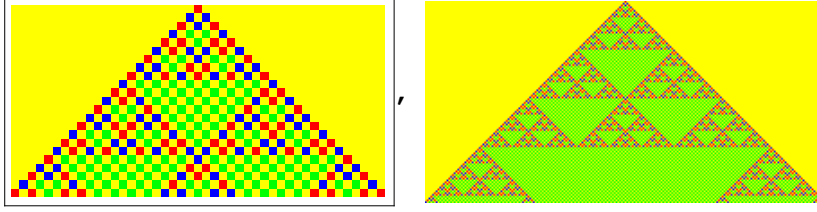
Therefore, many examples of morphoCA^(3,4) rules are different from ECA patterns albeit they are still defined in the classical architecture.

This holds for *ruleDM*[[1, 11, 3, 13, 15]], *ruleDM*[[1, 7, 3, 13, 15]] and the rules *ruleDCM*[[1,11,12,13,14]], *ruleDCM*[[1,2,12,13,14]] that are analogons of code 420.

Hence, there are at least 4 deviant forms in morphoCA. It turns out that, in this context, most patterns of morphic CAs are non-conventional.

CAs defined by the DCKV-rules are set in a different architecture and are thus producing internally and architectonically different patterns.

***ruleDM*[[1, 11, 3, 13, 15]]**

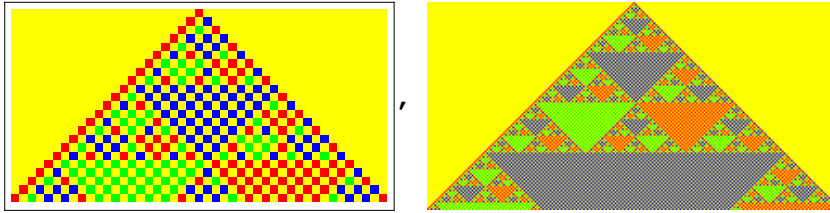


```

      {1}
    {2, 0, 2}
  {1, 0, 2, 0, 1}
 {2, 0, 3, 0, 3, 0, 2}
{1, 0, 1, 0, 3, 0, 1, 0, 1}
 {2, 0, 1, 0, 2, 0, 2, 0, 1, 0, 2}
{1, 0, 3, 0, 3, 0, 2, 0, 3, 0, 3, 0, 1}
 {2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2}
{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1}
 {2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2}
{1, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1}
 {2, 0, 1, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 1, 0, 2}
{1, 0, 3, 0, 3, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 3, 0, 3, 0, 1}
 {2, 0, 2, 0, 3, 0, 2, 0, 2, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2, 0, 3, 0, 2}
{1, 0, 1, 0, 3, 0, 2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2, 0, 3, 0, 1, 0, 1}
 {2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1}
{1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1}
 {2, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2}
{1, 0, 2, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 1, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 2, 0, 1}
 {2, 0, 3, 0, 3, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 3, 0, 3, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 3, 0, 3, 0, 2}
{1, 0, 1, 0, 3, 0, 1, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2, 0, 3, 0, 2, 0, 2, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 3, 0, 1, 0, 1}

```

ruleDM[{1, 7, 3, 13, 15}]

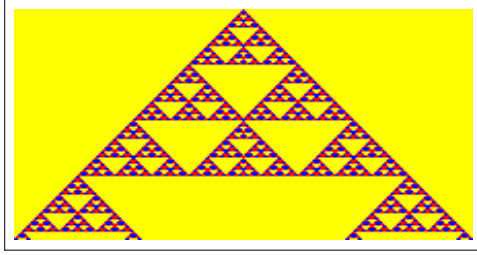


```

      {1}
    {1, 0, 2}
  {1, 0, 3, 0, 1}
 {1, 0, 2, 0, 2, 0, 2}
{1, 0, 3, 0, 2, 0, 2, 0, 1}
 {1, 0, 2, 0, 1, 0, 2, 0, 3, 0, 2}
{1, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 1}
 {1, 0, 2, 0, 3, 0, 3, 0, 2, 0, 1, 0, 1, 0, 2}
{1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1, 0, 3, 0, 1}
 {1, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2}
{1, 0, 3, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 1}
 {1, 0, 2, 0, 1, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 3, 0, 2}
{1, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 1, 0, 1, 0, 1}
 {1, 0, 2, 0, 3, 0, 3, 0, 1, 0, 2, 0, 2, 0, 2, 0, 2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 2}
{1, 0, 3, 0, 1, 0, 3, 0, 2, 0, 3, 0, 2, 0, 2, 0, 2, 0, 1, 0, 2, 0, 1, 0, 3, 0, 1}
 {1, 0, 2, 0, 2, 0, 2, 0, 1, 0, 1, 0, 2, 0, 2, 0, 2, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2, 0, 2}
{1, 0, 3, 0, 2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2, 0, 1, 0, 3, 0, 3, 0, 1, 0, 2, 0, 2, 0, 1}
 {1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 3, 0, 2, 0, 3, 0, 2, 0, 3, 0, 2, 0, 3, 0, 2}
{1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}
 {1, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}
{1, 0, 3, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1}
 {1, 0, 2, 0, 2, 0, 2, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 2, 0, 2, 0, 2, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2, 0, 2, 0, 2}
{1, 0, 3, 0, 2, 0, 2, 0, 1, 0, 3, 0, 3, 0, 3, 0, 3, 0, 3, 0, 1, 0, 2, 0, 2, 0, 3, 0, 1, 0, 1, 0, 1, 0, 1, 0, 3, 0, 2, 0, 2, 0, 1}

```

morphoCA^(3,3) ruleDCM[{1, 11, 12, 13, 14}]



```

      {1}
    {2, 2, 2}
  {1, 1, 2, 1, 1}
{2, 2, 0, 0, 0, 2, 2}
{1, 1, 1, 1, 0, 1, 1, 1, 1}
{2, 2, 1, 1, 2, 2, 2, 1, 1, 2, 2}
{1, 1, 0, 0, 0, 0, 2, 0, 0, 0, 0, 1, 1}
{2, 2, 2, 2, 0, 0, 1, 1, 1, 0, 0, 2, 2, 2, 2}
{1, 1, 2, 2, 1, 1, 2, 2, 1, 2, 2, 1, 1, 2, 2, 1, 1}
{2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 2}
{1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1}
{2, 2, 1, 1, 2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 1, 1, 2, 2}
{1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1}
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{1, 1, 1, 1, 0, 0, 2, 2, 2, 2, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 2, 2, 2, 2, 0, 0, 1, 1, 1, 1}
{2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 1, 1}
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{1, 1, 2, 2, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 1, 1, 2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 2, 2, 1, 1}
{2, 2, 0, 0, 0, 0, 2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 0, 0, 0, 0, 2, 2}
{1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 2, 0, 0, 2, 2, 2, 2, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1}

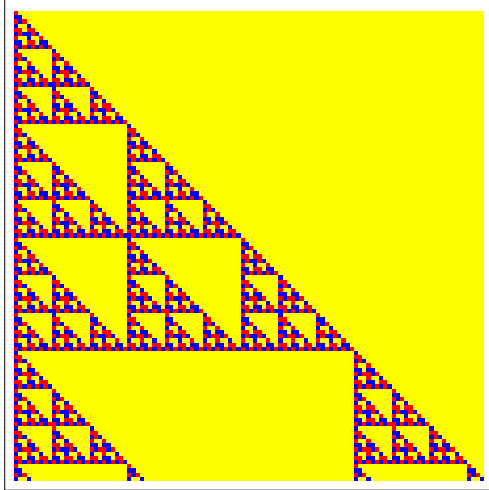
```

```

      1
      14
      35
      198
      495
      3698
      6275
      61918
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      786438
      1966095
      14942322
      25559235
      255592350
      638980875
      3247202502
      8306751375
      61847581490
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      1030793986078
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      33501004432335

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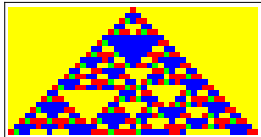
morphoCA^(3,3) ruleDCM[{1, 2, 12, 13, 14}]



{1}	1
{2, 2}	6
{1, 2, 1}	9
{2, 0, 0, 2}	18
{1, 1, 0, 1, 1}	27
{2, 1, 2, 2, 1, 2}	108
{1, 0, 0, 2, 0, 0, 1}	81
{2, 2, 0, 1, 1, 0, 2, 2}	414
{1, 2, 1, 2, 1, 2, 1, 2, 1}	681
{2, 0, 0, 0, 0, 0, 0, 0, 2}	1026
{1, 1, 0, 0, 0, 0, 0, 0, 1, 1}	1539
{2, 1, 2, 0, 0, 0, 0, 0, 2, 1, 2}	6156
{1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1}	4617
{2, 2, 0, 2, 2, 0, 0, 0, 0, 2, 2, 0, 2, 2}	27 702
{1, 2, 1, 1, 2, 1, 0, 0, 0, 1, 2, 1, 1, 2, 1}	41 553
{2, 0, 0, 1, 0, 0, 2, 0, 0, 2, 0, 0, 1, 0, 0, 2}	70 794
{1, 1, 0, 2, 2, 0, 1, 1, 0, 1, 1, 0, 2, 2, 0, 1, 1}	124 659
{2, 1, 2, 1, 2, 1, 2, 1, 2, 2, 1, 2, 1, 2, 1, 2, 1}	437 076
{1, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 1}	263 169
{2, 2, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 2, 2}	1 574 406
{1, 2, 1, 0, 0, 0, 0, 0, 2, 1, 2, 0, 0, 0, 0, 0, 0, 1, 2, 1}	2 365 449
{2, 0, 0, 2, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 2, 0, 0, 2}	4 723 218
{1, 1, 0, 1, 1, 0, 0, 0, 0, 2, 2, 0, 2, 2, 0, 0, 0, 0, 1, 1, 0, 1, 1}	7 105 563

A further slightly deviant analog to code 420

`ruleDM[{1, 11, 12, 13, 15}]`

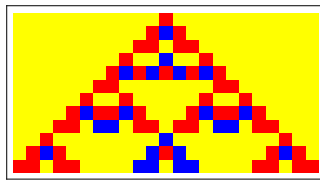


{1}	1
{2, 2, 2}	14
{1, 3, 2, 1, 1}	51
{2, 2, 0, 0, 0, 2, 2}	198
{1, 3, 1, 1, 0, 1, 3, 1, 1}	759
{2, 2, 2, 2, 2, 2, 2, 2, 2, 1, 1}	4094
{1, 3, 2, 2, 2, 2, 2, 2, 2, 2, 0, 2, 2}	14 331
{2, 2, 0, 0, 2, 2, 2, 2, 2, 2, 0, 0, 2, 2}	53 222
{1, 3, 1, 1, 1, 3, 2, 2, 2, 2, 1, 1, 3, 1, 1}	202 695
{2, 2, 2, 2, 1, 2, 0, 0, 2, 2, 2, 0, 0, 1, 2, 2, 2, 2, 2}	1 019 486
{1, 3, 2, 2, 0, 0, 3, 1, 1, 3, 2, 1, 1, 2, 3, 0, 2, 2, 2, 1, 1}	3 478 779
{2, 2, 0, 0, 1, 2, 2, 2, 2, 0, 0, 0, 0, 1, 1, 3, 2, 0, 0, 2, 2}	13 222 214
{1, 3, 1, 1, 2, 2, 0, 0, 2, 2, 1, 1, 0, 0, 2, 2, 0, 1, 1, 3, 1, 1}	51 603 271
{2, 2, 2, 2, 0, 1, 1, 3, 0, 0, 2, 2, 0, 1, 3, 2, 1, 3, 2, 1, 2, 2, 2, 2}	253 942 622
{1, 3, 2, 2, 1, 1, 2, 2, 1, 2, 2, 1, 1, 3, 1, 3, 2, 0, 0, 0, 0, 0, 2, 2, 2, 1, 1}	913 129 531
{2, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 0, 1, 1, 0, 0, 0, 0, 1, 3, 2, 0, 0, 2, 2}	3 221 696 710
{1, 3, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 3, 2, 1, 3, 2, 2, 2, 0, 0, 0, 2, 2, 0, 1, 1, 3, 1, 1}	12 349 825 863
{2, 2, 2, 2, 2, 0, 0, 0, 0, 0, 0, 0, 2, 2, 0, 0, 0, 0, 2, 1, 0, 1, 3, 1, 3, 2, 1, 2, 2, 2, 2}	67 652 074 846
{1, 3, 2, 2, 2, 1, 1, 0, 0, 0, 0, 0, 1, 3, 1, 1, 0, 0, 1, 3, 0, 2, 2, 2, 2, 2, 0, 0, 0, 2, 2, 1, 1}	237 858 126 907
{2, 2, 0, 0, 2, 2, 0, 0, 2, 2, 0, 0, 0, 2, 2, 2, 2, 2, 0, 1, 3, 2, 2, 1, 1, 0, 0, 1, 3, 2, 0, 0, 2, 2}	879 527 704 262
{1, 3, 1, 1, 1, 3, 1, 1, 1, 3, 1, 0, 1, 3, 2, 2, 2, 2, 1, 1, 3, 2, 0, 0, 0, 0, 2, 2, 2, 2, 0, 1, 1, 1, 3, 1, 1}	3 371 479 093 063
{2, 2, 2, 2, 1, 2, 2, 2, 1, 2, 2, 2, 2, 2, 2, 0, 0, 2, 2, 0, 0, 1, 1, 0, 0, 1, 1, 1, 3, 2, 2, 1, 3, 2, 1, 2, 2, 2, 2, 2}	17 299 697 112 926
{1, 3, 2, 2, 0, 0, 2, 0, 0, 2, 2, 2, 1, 1, 1, 3, 1, 1, 1, 1, 3, 2, 2, 2, 2, 1, 1, 2, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 1, 1}	57 482 908 991 547

`morphoCA(3,3) ruleDM[{1, 11, 12, 13, 14}]`

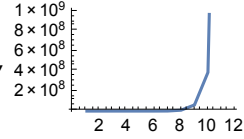
Examples

`ruleDM[{1, 7, 12, 4, 10}]`

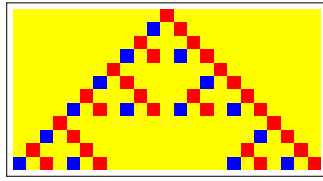


$$\left(\begin{array}{c} \{1\} \\ \{1, 2, 1\} \\ \{1, 1, 0, 1, 1\} \\ \{1, 0, 0, 2, 0, 0, 1\} \\ \{1, 2, 1, 2, 1, 2, 1, 2, 1\} \\ \{1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1\} \\ \{1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1\} \\ \{1, 2, 1, 1, 2, 1, 0, 0, 0, 1, 2, 1, 1, 2, 1\} \\ \{1, 1, 0, 2, 2, 0, 1, 1, 0, 1, 1, 0, 2, 2, 0, 1, 1\} \\ \{1, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 1\} \\ \{1, 2, 1, 0, 0, 0, 0, 0, 0, 2, 1, 2, 0, 0, 0, 0, 0, 0, 1, 2, 1\} \\ \{1, 1, 0, 1, 1, 0, 0, 0, 0, 2, 2, 0, 2, 2, 0, 0, 0, 0, 1, 1, 0, 1, 1\} \end{array} \right)$$

1
16
112
784
12 301
78 736
551 152
8 818 432
61 729 024
387 459 856
6 199 180 549
43 395 503 872

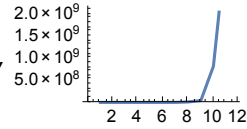


ruleDM[{1, 11, 3, 4, 10}]

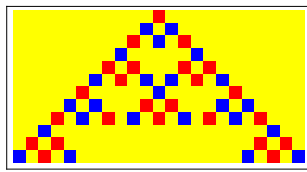


$$\left(\begin{array}{c} \{1\} \\ \{2, 0, 1\} \\ \{1, 0, 0, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 0, 0, 0, 0, 0, 0, 1\} \\ \{2, 0, 1, 0, 0, 0, 0, 0, 2, 0, 1\} \\ \{1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1\} \\ \{2, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 1\} \\ \{1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 1, 0, 2, 0, 1\} \end{array} \right)$$

1
19
82
1558
6562
124 678
538 084
10 223 596
43 046 722
817 887 718
3 529 831 204
67 066 792 876

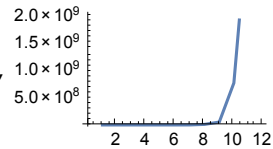


ruleDM[{1, 11, 3, 13, 10}]

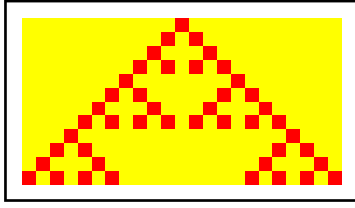


$$\left(\begin{array}{c} \{1\} \\ \{2, 0, 2\} \\ \{1, 0, 2, 0, 1\} \\ \{2, 0, 0, 0, 0, 0, 2\} \\ \{1, 0, 1, 0, 0, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 2, 0, 1, 0, 2\} \\ \{1, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 1\} \\ \{2, 0, 2, 0, 0, 0, 1, 0, 1, 0, 0, 0, 2, 0, 2\} \\ \{1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1, 0, 2, 0, 1\} \\ \{2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2\} \\ \{1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1\} \\ \{2, 0, 1, 0, 2, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 0, 1, 0, 2\} \end{array} \right)$$

1
20
100
1460
7300
126 290
532 900
10 636 130
53 270 317
774 840 980
3 874 204 900
67 023 744 770



Contrast ECA rule 90

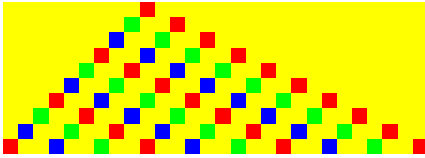


$$\left(\begin{array}{c} \{1\} \\ \{1, 0, 1\} \\ \{1, 0, 0, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 0, 0, 0, 0, 0, 1\} \\ \{1, 0, 1, 0, 0, 0, 0, 1, 0, 1\} \\ \{1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \\ \{1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1\} \\ \{1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1\} \\ \{1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1\} \end{array} \right), \left(\begin{array}{c} 1 \\ 5 \\ 17 \\ 85 \\ 257 \\ 1285 \\ 4369 \\ 21845 \\ 65537 \\ 327685 \\ 1114129 \\ 5570645 \end{array} \right)$$

Reduction in morphoDCKV

ruleDCKV[{1111, 1123, ...}] :

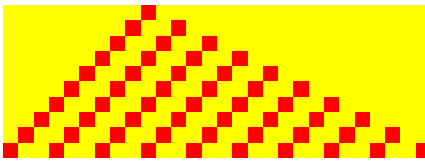
$$\left(\begin{array}{c} \{1\} \\ \{3, 0, 0, 1\} \\ \{2, 0, 0, 3, 0, 0, 1\} \\ \{1, 0, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{1, 0, 0, 2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \\ \{1, 0, 0, 2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1, 0, 0, 2, 0, 0, 3, 0, 0, 1\} \end{array} \right),$$



$\Downarrow_{2,3 \rightarrow 1}$

ruleDCKV[{1111, 1122, ...}] :

$$\left(\begin{array}{c} \{1\} \\ \{1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \\ \{1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1\} \end{array} \right),$$



Examples for morphoCA^(5,5,5)

Requisites

Procedures morphoDCKV

Rules

```
(Debug) Out[3582]=
```

a

1111	1112
------	------

b

1120	1121	1122	1123
------	------	------	------

c

1210	1211	1212	1213
------	------	------	------

d

1220	1221	1222	1223
------	------	------	------

e

2120	2121	2122	2123
------	------	------	------

f

2210	2211	2212	2213
------	------	------	------

g

2220	2221	2222	2223
------	------	------	------

h

2110	2111	2112	2113
------	------	------	------

i

2130	2131	2132	2133	2134
------	------	------	------	------

j

1230	1231	1232	1233	1234
------	------	------	------	------

k

2230	2231	2232	2233	2234
------	------	------	------	------

l

2310	2311	2312	2313	2314
------	------	------	------	------

m

2320	2321	2322	2323	2324
------	------	------	------	------

n

2330	2331	2332	2333	2334
------	------	------	------	------

o

2340	2341	2342	2343	2344
------	------	------	------	------

width

2 3 4 5

mesh

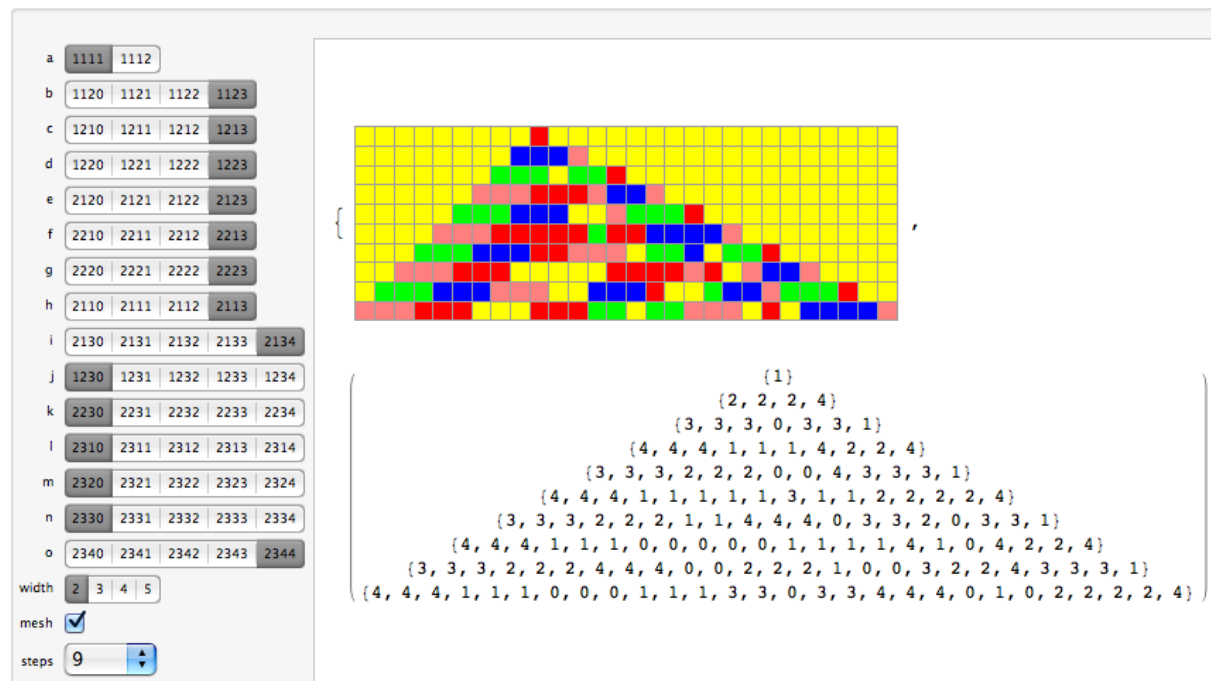
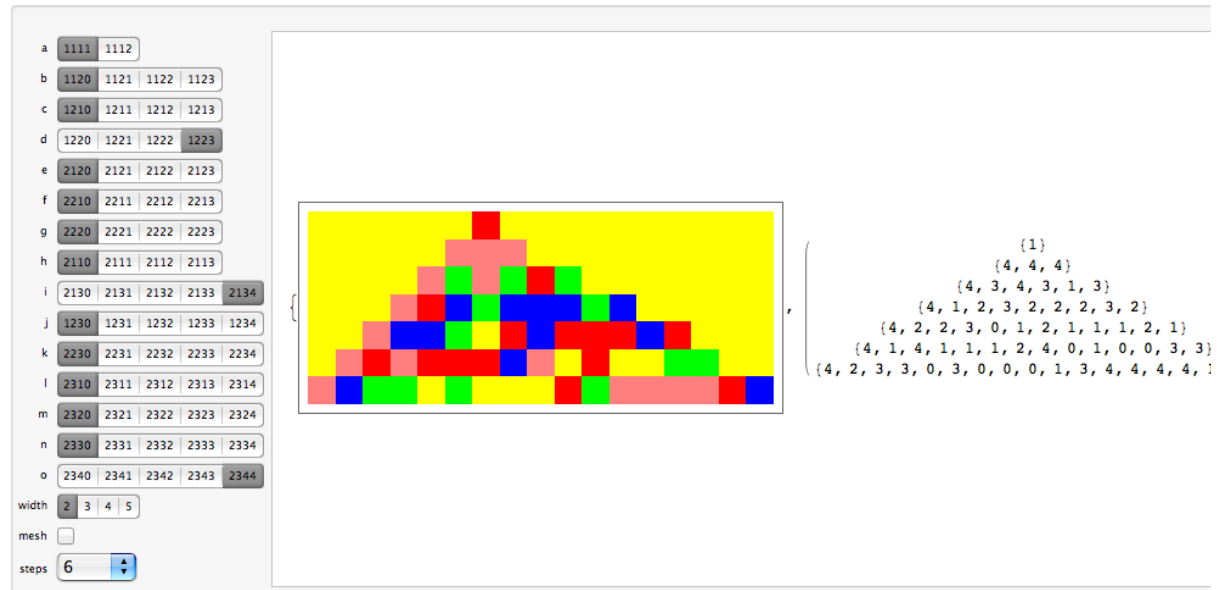
☐

steps

V

The diagram illustrates a spatial domain partitioned into three vertical sections. The top section consists of three adjacent rectangles: a yellow one on the left, a red one in the center, and another yellow one on the right. A bracket on the far left indicates the height of this top section. Below the top section is a single, wide green rectangle that spans the entire width of the diagram.

Examples



[illegible]

1
562 949 953 421 379
1125 899 906 842 692
1 688 849 860 264 003
1 285 799 813 683 464
190
562 949 953 423 711
1125 899 906 844 862
1 688 849 860 266 173
2 251 799 813 628 284
190
562 949 953 498 111
1125 899 906 914 302
1 688 849 860 335 613
2 251 799 811 862 524
190
562 949 955 878 911
1125 899 909 136 382
1 688 849 862 557 693
2 251 799 755 358 204
190
562 950 932 064 511
1125 899 980 242 942
1 688 849 933 664 253
2 251 797 947 219 964
190
562 952 470 003 711
1125 902 255 652 862
1 688 852 209 074 173
2 251 740 086 796 284
190
563 030 484 058 111
1125 975 088 770 302
1 688 925 022 192 613
2 249 888 553 238 524
190
565 526 933 798 911
1126 305 088 528 382
1 691 255 041 949 693
2 190 639 479 390 204
190
645 413 325 504 511
1202 865 720 786 942
1 765 815 674 208 253
294 669 116 243 964